

Multi-channel LED driver by using single buck controller

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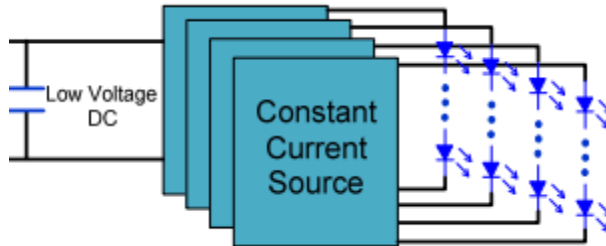
Multi-channel LED driver proposal

This concept can use for dimming, color mixing and for color temperature tuning.

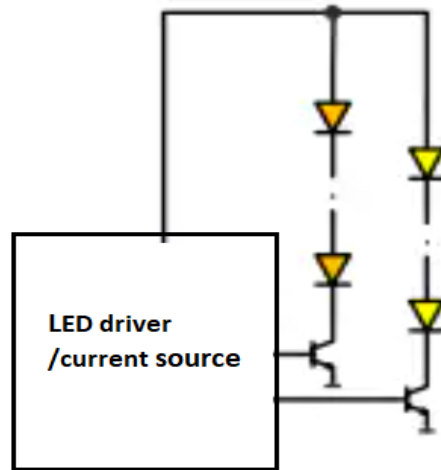
Existing Devices:

Existing constant current LED drivers use a flyback for controlling the Power Factor Correction (PFC). Each LED channel has an independent buck controller to controlling the LED current. However, this requires more space and more construction cost.

Existing products are using two types of techniques to control the mutli-channel LEDs' current / color. The first technique uses an independent constant current source for each LED string. Each LED string current controlled by independent constant Current source. As such, the number of current sources are directly proportional to the number of channels (e.g., a four channel LED driver will have four independent current sources. However, disadvantage are that more printed circuit board (PCB) space is needed and construction cost is higher. Below is a block diagram of this first technique:



The second technique is to use one constant current source with MOSFET's. The output of the constant current source is connected to the MOSFET's. The number of MOSFET's is directly proportional to the number channels. For example, four MOSFET's are required for a four channel LED driver. The LED color is controlled by MOSFET's turning ON and OFF. This results in a buzzing noise being generated. Also each LED strip voltage needs to be substantially identical, otherwise spikes in LED current will be caused. Below is a block diagram of this second technique:



Proposed Concept:

Current and color are controlled by a single current source and MOSFETs (Q1,Q6,Q8 and Q10). MOSFET-resistor network (Q12 and R100) helps eliminate the LED current spikes and buzzing noise.

The proposed concept also has a flyback controller for PFC. The LED current is controlled by a single buck controller. The LED current will switch to different channel by using MOSFET's and MOSFET-resistor network (Q12 and R100) to avoid current spikes/overshoot in the LED's current while turning ON the MOSFETs (Q1, Q6, Q8 and Q10). The MOSFET-resistor network is connected across the current source output. The microcontroller measures the current source output voltage before turning ON the MOSFETs (Q1,Q6,Q8 and Q10). The Q12 MOSFET turns ON if the current source voltage is higher than the LED required voltage. The microcontroller keeps monitoring the current source output voltage. Q12 turns OFF once the current source voltage is less than the required LED voltage. This logic helps for eliminating the spike in the LED's current.

More specifically, the source terminal of MOSFET's (Q1, Q6, Q8 and Q10) are connected to the negative terminal of the current source. The drain terminals of the MOSFET's are connected to the respective LED's. These MOSFET's are turned ON and OFF depending on the current and color requirements (e.g., Q1 turned ON and Q6, Q8 and Q10 turned OFF to get a red color).

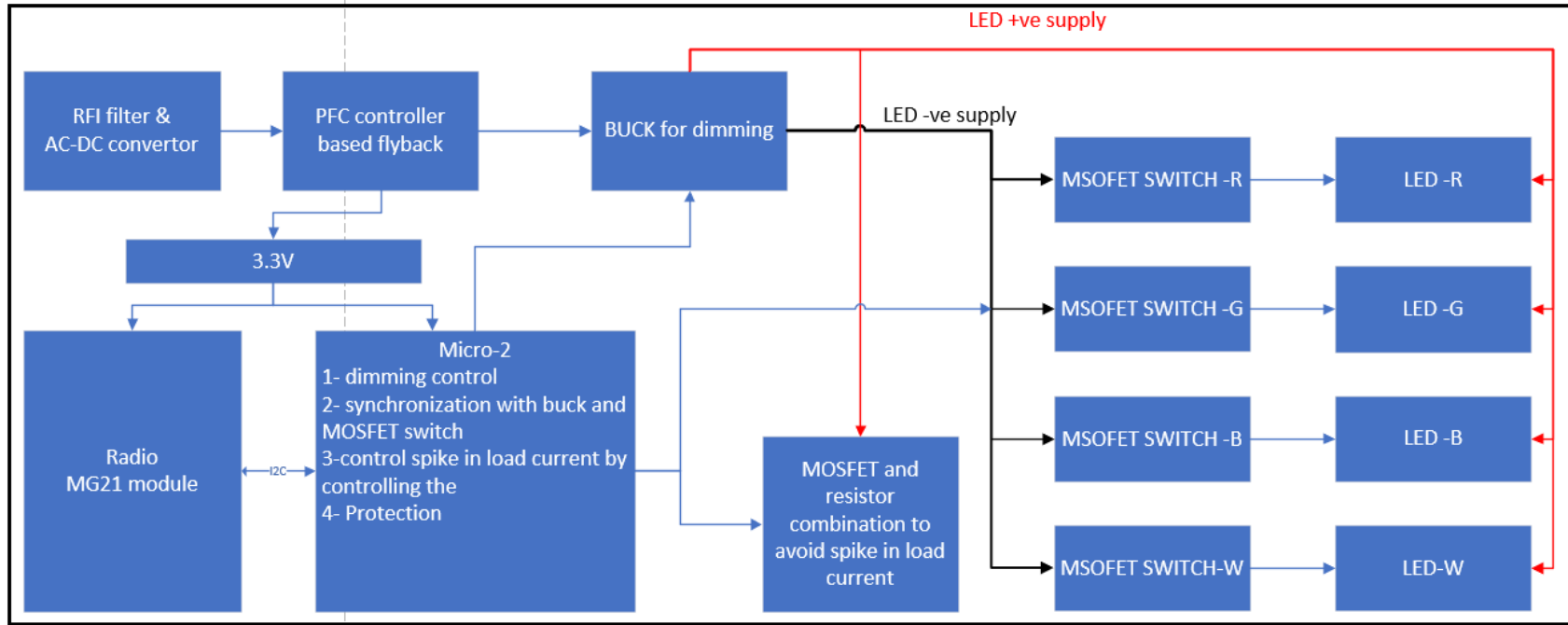
If the MOSFET's are simply turned ON and OFF, the MOSFET's will cause for the LED current to overshoot and create a buzzing sound. To avoid this issue, the buck controller is turned OFF before turning ON and OFF the MOSFET.

In general, the voltage on each channel will be different. So, the LED voltage needs to be monitored and the MOSFET- resistor network needs to be controlled to avoid current spikes. An algorithm is used to control the MOSFET and the MOSFET-resistor network to avoid such current spikes and noise.

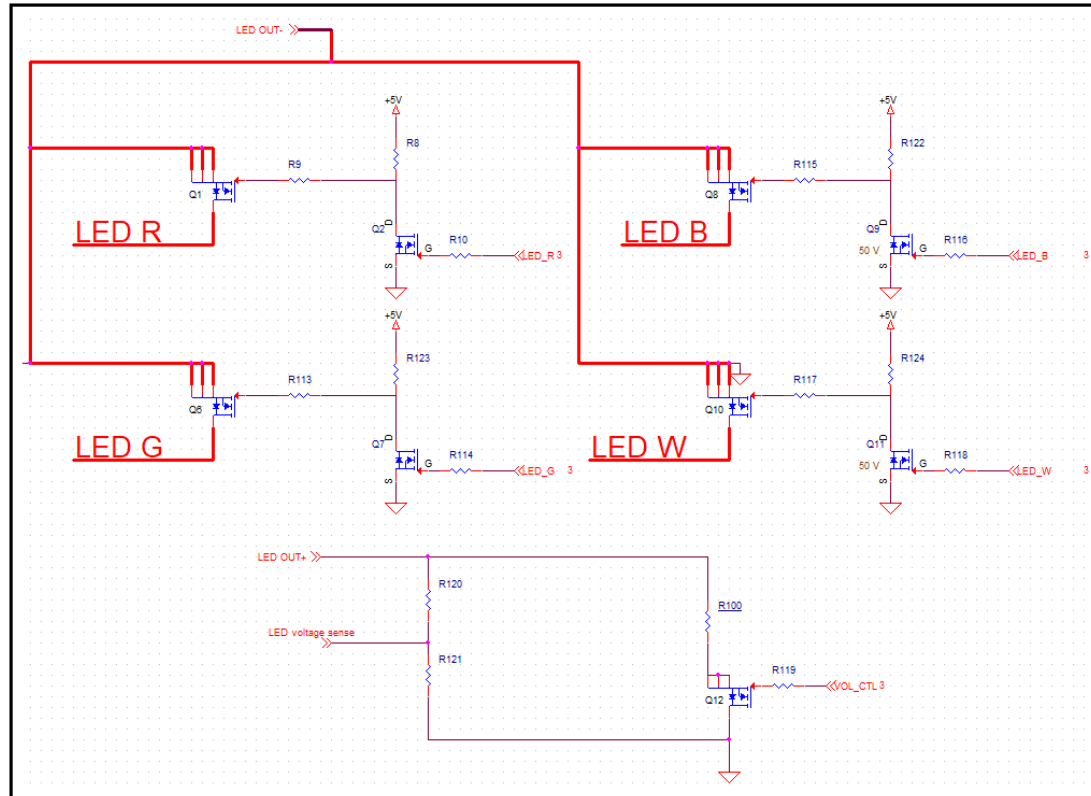
The output of the buck controller is connected to MOSFET's (depending on the channel requirements). The number of MOSFETs are same as number channels). The MOSFET's gates are controlled by a 500 Hz to 5 kHz square waveform. The MOSFET's duty cycle depend on the required LED color or required LED color temperature. Changing the MOSFET's duty cycle will result in different LED colors being generated. Dimming is controlled by the buck constant current controller and the MOSFET-resistor network is used to control the LED voltage.

- The below algorithm is used to avoid the LED's current spike and buzzing noise.
 1. Do the calibration at startup to find the LED strip (each channel) forward voltage
 1. Calibration start
 2. Connect only red LED strip (turn ON only Q1)
 3. Turn ON current source and record the LED strip forward voltage after stabilization.
 4. Turn OFF current source and turn ON Q12 to discharge the output capacitor stored energy quickly.
 5. Wait until current source output voltage less than the rated minimum LED voltage.
 6. Repeat from step 2 for green, blue, and white LEDs (connect only one LED strip /channel at a time).
 7. End of the calibration
 2. Record RGBW LED string voltage each cycle at the end of MOSFET gate signal. Follow below pattern to control the MOSFETs.
 1. Assume Q1 is ON – (current MOSFET state). It means red LED is ON as Q1 connected to the red LED.
 2. Turn OFF the current source.
 3. Wait for about one microsecond.
 4. Measure the current source output voltage.
 5. Turn ON Q12 if the current source output voltage greater than the recorded green LED voltage (e.g., the green LED will be turned on).
 6. Wait for the current source output voltage to be reduced to less than the recorded green LED voltage.
 7. Turn OFF red LED (Q1).
 8. Turn OFF Q12.
 9. Turn ON green LED (turn ON Q6)
 10. Repeat from second step to turn ON next LED.

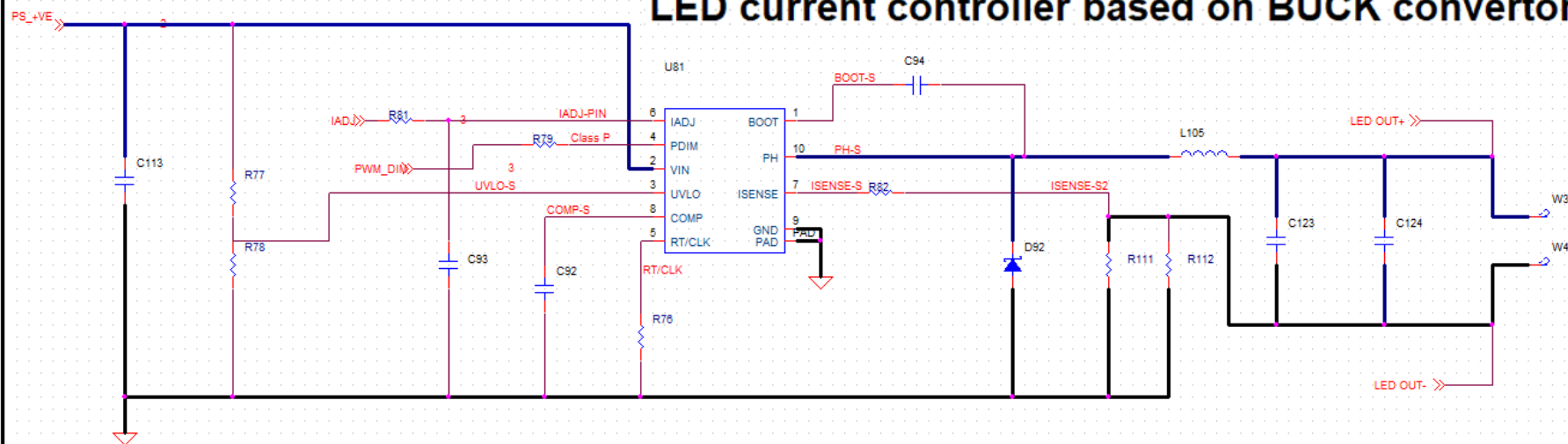
Concept : LED color controlled by MOSFET



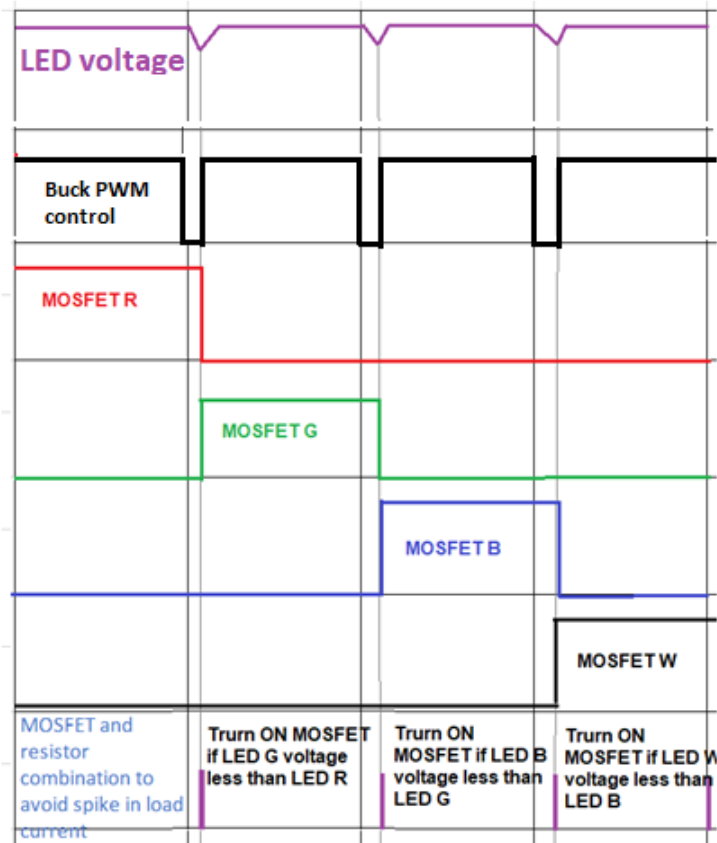
Concept: MOSFET circuit



LED current controller based on BUCK convertor



MOSFET timing diagram



Algorithm for turning ON MOSFET for color mix

- Do the calibration at startup to find the LED strip (each channel) forward voltage
- Record RGBW LED voltage each cycle at the end MOSFET gate signal.
- For turning ON MOSFET-G:
 - turn OFF buck first.
 - wait for $\sim 1\mu s$ to discharge the energy
 - check the LED voltage
 - turn ON MOSFET-Resistor network if LED voltage greater than MOSFET-G recorded voltage. Wait for reducing the LED voltage less than MOSFET-G recorded voltage.
 - Turn OFF MOSFET-R (or previously ON MOSFET) and MOSFET-resistor network and turn ON MOSFET G
- Follow step 3 for turning ON each MOSFET.
- Use same algorithm for LED color temperature tuning and dimming. Instead of 4 channel use 2 channel